Chapter 5: Effect-by-Effect Analysis

Overview

Like many environmental policies, Superfund produces a variety of benefits that do not have a natural, common metric for valuation.[1] To evaluate these benefits, an "effect by effect" analysis is useful (U.S. Environmental Protection Agency 2000, 59, 62-65). Effect-by-effect analysis usually involves classifying the physical effects of the pollutants (e.g., various types of damages to human health and ecological systems) and assessing each type of effect separately. Several effect-specific analyses are proposed in this chapter to estimate the benefits of some specific improvements in human health (i.e., lower health risk), ecological conditions, and ground water protection. Due to data limitations, only the benefits associated with NPL sites will be estimated, with one exception: the analysis of the benefits created by natural resource restorations. The estimates of benefits proposed in this chapter cannot be added to the estimate of benefits developed in Chapter 4 because there is the potential for double-counting of benefits by the two methods of estimation. This chapter has three major sections corresponding to the major classes of benefits: health effects, ecological effects, and ground water protection effects.

In several places in this chapter the text stops before the analysis being described is completed, by agreement with the EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed-upon process is for EPA to provide a description of the data and proposed methodology but not to go forward with an analysis until we receive input from the Advisory Panel on our intended approach.

Health

Overview

Like other environmental programs, a key motivation for the Superfund program is to reduce human health risks. The health risks presented by hazardous substances include acute effects (e.g., poisoning or injuries from fires or explosions) and a variety of long-termeffects (e.g., cancers or birth defects) (Johnson 1999; Bove, Shim, and Zeitz 2002; Dolk and Vrijheid 2003). Examples of the more than 250 hazardous substances that create these dangers and are addressed by the Superfund program include lead, arsenic, benzene, trichloroethylene, and mercury. Since 1990, completed exposure pathways for hazardous substances in the environment have been found at over 15,000 sites (NPL and non-NPL) in the United States (Agency for Toxic Substances and Disease Registry 2003a, 2003b). In addition, the Superfund program sometimes deals with substances that are explosive or radioactive (Probst and Konisky 2001, 20; Johnson 1999, 85).

This section contains a general review of the literature and data available on the epidemiology of hazardous substances in the environment. This is followed by five subsections on the valuation of health risks, birth defects, acute accidents and injuries, lead-induced health effects, and cancer and other health effects. In each of the subsections on specific health endpoints, a table that briefly summarizes the available data is presented.

[1] Here, Superfund is defined as all the activities and programs created by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA).

Literature on Health Effects

Uncontrolled releases of hazardous substances to the environment can increase the risk of adverse health effects to exposed populations, especially to sensitive sub-populations, such as children (Schettler 2001). Superfund mitigates these risks by interrupting exposure pathways and reducing the amount, mobility, and toxicity of hazardous substances found in the environment. Measuring the size of these health risk reductions is extremely challenging. The most robust method is site-specific risk assessment (Paustenbach 2002); however, this method is not used in this study. The main reason is resources – the time and budget allocated to this project were not sufficient to conduct a formal risk assessment of a meaningful sample of Superfund sites.

EPA conducts risk assessments for all sites on the National Priorities List (NPL) as part of the NPL process (specifically in the baseline risk assessment, or BLRA, see Figure 3.1), but these data are both limited in availability and applicability. These data are limited in availability (or perhaps accessibility) because, like much of the data associated with Superfund, they are not collected in a single database or location. Summaries of these studies are available in the Records of Decision (ROD) for each NPL site, but the BLRAs are usually only available in hard copy at the appropriate Regional EPA office. More importantly, BLRAs are only conducted for NPL sites, which are a small fraction (less than 10%, see Chapter 3) of all responses. For removal actions and state responses, some documentation (e.g., an Action Memo for a removal) may be available, but even where documentation is available, it almost never includes a formal risk assessment. Indeed, one of the major distinctions between removal and remedial actions is that the removal process is designed to operate without formal risk assessments because they are not necessary for sound management decisions and because the delay they would cause would often have significant risk consequences of its own. However, the most important problem with the idea of using BLRAs or similar risk assessments in this analysis is that the conservative assumptions that are protective of human health on which they are based are appropriate for making decisions about remedies at NPL sites, but may not be appropriate for calculating benefits (Viscusi, et al. 1997; EPA Science Advisory Board 2002).

The level of effort required to conduct an effect-by-effect benefits analysis using EPA risk assessment data as a starting place is indicated by the size of the multi-year project that resulted in *Calculating Risks?*, which examined a single effect, adult cancer risk at NPL sites (Hamilton and Viscusi 1999). That study is particularly strong in terms of understanding those particular risks. Possible improvements, such as updating the choice of NPL sites and repeating the entire analysis or adding other health risks (e.g., birth defects or childhood cancer) and repeating that entire study, are beyond the scope of this study. Thus, the results from *Calculating Risks?* are used below in a benefit transfer analysis for reductions in cancer health risks.[2]

Other risks are even more difficult to analyze because of the lack of data. While EPA does quantitatively rate the non-cancer health risk with a "hazard quotient", this value does not identify the type of outcome, which can "range from drowsiness to death" and "does not translate exposure to varying levels of non-cancer risks into the probability of an actual adverse outcome"

[2] In this version of the Superfund Benefits Analysis, no effect-by-effect health analysis is actually conducted, even though the introductory material is written as if it is. Through agreement with the EPA Science Advisory Board, methodologies are only proposed.

(Hamilton and Viscusi 1999, 53, 107). Even the more extensive data collected by the Agency for Toxic Substances and Disease Registry (ATSDR) do not provide the information needed for a formal risk assessment of non-cancer risks (General Accounting Office 1999; Agency for Toxic Substances and Disease Registry 2003a, 2003b). Thus, a different approach is needed.

The other feasible approaches to estimating the risk reduction benefits for specific health outcomes due to the Superfund program are i) to use the results of risk exposure models, ii) epidemiological studies, or iii) benefits transfer methods. These approaches have their own limitations, but they at least can provide some insight into the magnitude of the adverse health outcomes associated with uncontrolled releases of hazardous substances. Model-based approaches allow an estimate of the benefits of Superfund by reducing exposures through response actions, but the available epidemiological data only allow an estimate of the potential magnitude of the negative health effects associated with releases.

This study examines five categories of health effects: acute accidents and injuries; adult cancer; birth defects (also known as congenital anomalies); lead-induced health effects (mostly reduction in cognitive abilities, usually measured by decreases in IQ scores); and other chronic non-carcinogenic effects (e.g., thyroid dysfunction, endometriosis, etc.). As mentioned above, cancer risk reductions are estimated using a simple benefit transfer of the results from Hamilton and Viscusi (1999). EPA's Integrated Exposure Uptake Biokinetic model (IEUBK) is used to estimate the benefits of reducing lead exposure. Epidemiological data is used to estimate the potential magnitude of the negative health effects from acute accidents, birth defects, and other negative health outcomes.

For acute injuries, birth defects, and other chronic non-carcinogenic effects, epidemiological data are used to estimate the number of additional cases, following the approach used in a peer-reviewed paper, "Medical costs and lost productivity from health conditions at volatile organic compound-contaminated Superfund sites"(Lybarger et al. 1998), but using more recent and more detailed population data.[3] This method has three basic steps. First, relationships between specific substances and specific health endpoints are established based on published epidemiological research. The rates of excess occurrence are also estimated. Second, sites are identified at which completed exposure pathways for the specific substance exist (or existed in the past, prior to a response). Then, an exposed population is estimated by determining the number of residents (using the 2000 Census) within ½ mile (a value derived from a review by Lybarger et al. of all the relevant site assessment data collected by ATSDR). This approach can be applied only to NPL sites, because location data is available only for these sites. This limitation means that removal actions must be ignored in this analysis.

The number of excess cases is then calculated by taking the product of the exposed population and the rate of excess cases. Finally, the economic value of these excess cases is estimated by calculating the product of the number of excess cases and the cost of illness (COI) for that specific health endpoint, using the data from EPA's *Cost of Illness Handbook*, which is described below. This provides a rough estimate of the magnitude of the health risks, which should be

[3] Discussions with several of the authors of this paper indicated that they felt further applications such as those discussed here were likely to yield reasonable estimates of the effect.

close to the benefit of the Superfund program, assuming that the relevant exposure pathways are interrupted and no new ones are created. This seems to be a reasonable assumption.

A recent book summarizes much of the literature on the health effects of hazardous waste (Johnson 1999). The most comprehensively researched health risk associated with NPL sites is adult cancer; the work by Hamilton and colleagues is probably the most relevant and useful but there is some more recent work in this area as well (Costas, Knorr, and Condon 2002; Hamilton and Viscusi 1999). Several recent summaries of the effects of acute injures (e.g., inhalation of chlorine gas, explosions, etc.) are available (Horton, Berkowitz, and Kaye 2004; Zeitz et al. 2000; Palmer, Rees, and Coleman 2000). There is a large body of literature on increased incidence of birth defects associated with hazardous waste sites (Vrijheid et al. 2002; Bove, Shim, and Zeitz 2002; Castilla et al. 2001; Orr et al. 2002; Costas, Knorr, and Condon 2002; White et al. 1997; Bove et al. 1995). The principal health problems identified in the literature appear to be cardiac malformations and various central nervous system defects. The health impacts of lead at a few Superfund sites are fairly well documented, and there is good evidence of a general relationship between soil lead and elevated blood lead levels (Johnson and Bretsch 2002; von Lindern, Spalinger, Bero et al. 2003; von Lindern, Spalinger, Petroysan et al. 2003). The health risks due to response actions have received some analysis, suggesting that the greatest risks are to unborn children of mothers working on responses, and nearby children (Mushak 2003). However, in one study of cleanup of a lead smelter, exposure to neighboring children (and other residents) due to the cleanup was shown to be trivial (Khoury and Diamond 2003).

This literature is plagued by a lack of exposure data, making it very difficult to sort out exposed from non-exposed populations (Harrison 2003). Exposure occurs when five elements are present: a source of contamination, an environmental medium and transport mechanism, a route of exposure, a point of exposure, and a receptor population. (For a general discussion of this issue, see Williams and Paustenbach 2002.) Exposure to hazardous substances varies significantly from site to site, and human exposure to hazardous substances may occur through multiple routes. Some data on human exposure due to uncontrolled releases of hazardous substances exist for some cases but no collection of exposure data useful for an overall analysis of expected risk is available.[4] However, research based on site-specific investigations at NPL sites suggests that the most important exposure medium is ground water, followed by soil, air, biota, and other media, and that ingestion is by far the most important exposure pathway, followed by dermal contact and inhalation (Hamilton and Viscusi 1999, 24-57). Nonetheless, the lack of definitive exposure data limits the analysis that is possible in this study (Harrison 2003).

The estimation of the benefits of reducing these health risks involves two essential steps: estimating the number of negative health outcomes (cases) avoided, and valuing the avoidance of each outcome (case). The first step will be accomplished differently, as mentioned above, for each effect, while the second step will be accomplished in the same way for all, through the use of a "cost of illness" approach. The details of the method used for quantifying the avoided

[4] Specifically, exposure and risk information for the maximally exposed individual (MEI) exists for most sites on the National Priorities List (NPL), but neither data for typical individuals nor population exposure data exist for these sites. Even less information is available for other sites with uncontrolled releases of hazardous substances, which are far greater in number (see Chapter 2).

outcomes are discussed in each of the sections below on specific effects, while valuation is discussed in the section below.

Valuation of Health Effects
The value of health risk reductions can be estimated by calculating the costs of the negative health outcome and using that amount for the value of an avoided case. Ideally, valuation of these human health benefits would include all costs to society associated with the benefits, including medical costs, work-related costs, educational costs, the cost of support services required by medical conditions, and the willingness of individuals to pay to avoid the health risks. Taken together, these factors could be called society's total willingness to pay to avoid illness. Most of this information is difficult to obtain, so accurate estimates of society's total willingness-to-pay to avoid illness are not usually possible. Consequently, alternative measures of the costs saved when illnesses are avoided may be used instead. Direct medical costs, which measure non-subjective aspects of an illness — the expenditures on medical care — are often used as lower-bound estimates of the benefits of avoiding an illness.

EPA's *Cost of Illness Handbook* provides a relatively straight-forward approach to calculating the medical and related costs avoided (U.S. Environmental Protection Agency 2002; Waitzman, Romano, and Scheffler 1994). The medical costs in this handbook provide a relatively simple and efficient lower-bound estimate of the costs of illnesses. The goal of the handbook is to provide cost estimates that are generalizable to any area of the United States. To obtain cost data representative of the nation as a whole, standard disease treatment methods, using generally acceptable practices, and the average patient experience regarding prognosis and survival (e.g., life expectancy) were used in cost estimates.

Thus, the cost of illness (COI) data provided in the handbook include some, but not all, of the components of the total benefit of avoiding a disease. Those outside the scope of this analysis are direct non-medical costs, the opportunity costs of patients, family members, or other unpaid caregivers, and what the patient and others would be willing to pay to avoid the anxiety, pain, and suffering associated with the illness. Due to the seriousness of most illnesses in this handbook, these components may be substantial.

The direct medical costs incurred as the result of an illness were estimated for the duration of the illness, i.e., from diagnosis to cure or patient death. However, this approach does not estimate the willingness to pay to avoid a premature death. Expected costs are estimated for each year post-diagnosis until cure or death, incorporating information on the likelihood and timing of receiving specific treatments, as well as survival data, information on the age of onset of the disease, and life expectancy data. Medical cost estimates are subject to advances in medical practice and changes in the costs of both services and materials. Most cost estimates are based on recent evaluations of medical practice; the handbook provides dates when cost and treatment data were obtained and descriptive information regarding disease definition and treatment. The user should consider changes in practice over time, however, if recent advances or changes in treatment have been reported.

The main advantages of the COI approach are that it is straightforward to implement, easy to understand, and likely to be accurate for the parts of willingness to pay (WTP) that it actually attempts to measure, the medical cost component. The main disadvantage is that it leaves unmeasured some potentially significant costs.

Birth Defects

Over a dozen studies on the health effects associated with sites that have hazardous substances have been published in the peer-reviewed literature since 1990, as well as several review articles. Almost all of these studies have appeared in the public health and medical literature and none of them have been referenced in the economics or risk assessment literature. The authors of these health studies uniformly decry the lack of adequate data for the task, and in particular the almost complete absence of exposure data. As a result, they are often forced to rely on proximity as a proxy for exposure.

Table 5.1 summarizes studies of birth defects and hazardous substances, reporting the odds ratios (OR) and associated confidence intervals (CI), along with some summary notes about the studies and their results. The OR is calculated by dividing the odds in the exposed group by the odds in the control group, where the odds of an event is the number of events (live births with birth defects) divided by the number of non-events (live births without birth defects). If the odds ratio is less than one then the odds (and therefore the risk) have decreased, and if the odds ratio is greater than one then they have increased. In epidemiological studies such as those in Table 5.1, the purpose is typically to identify factors that cause harm - those with odds ratios greater than one. When the risks (or odds) in the two groups being compared are both small (say less than 20%) then the odds will approximate the risks and the odds ratio will approximate the relative risk. The odds of any congenital malformation is less than 2% in the United States, and the odds of specific conditions is lower than that (Anonymous 2003). Thus, ORs for birth defects closely approximate increased risks, so an entry in Table 5.1 of an OR of 1.12 implies approximately a 12% increased risk, while an OR of three implies three times as much risk.

There are significant limitations to this approach. Relying solely on epidemiological studies would introduce significant uncertainties about causation. The assumption that proximity is an adequate proxy for exposure means that (1) epidemiological studies may not take into account the technology of disposal (e.g., well-designed hazardous waste landfills may significantly limit the release of contaminants); (2) there is no significant evaluation of exposure pathways; and, (3) it is difficult to control for some confounding factors, such as other industrial facilities and background pollutant levels. However, epidemiological data rely on known effects to humans, avoiding the uncertainties associated with approaches that rely on toxicological or assumptions in exposure models.

This discussion stops here without completing the analysis by agreement with the EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

Table 5.1. Studies of Birth Defects and Hazardous Materials

Study	Health endpoints	Results (95% CI)	Notes
(Goldberg et al. 1990)*	Heart defects	OR for children of parents with VOC contaminated water: 3 ($p<0.005$) Returned to near unity after well closure	Cited by Lybarger. Area not given. Trichloroethylene exposure in drinking water in Tucson up to 239 ppb.
(Geschwind et al. 1992)*	Birth defects (all) CNS MUS Skin defects Oral clefts	OR 1.12 (1.06 - 1.18) OR 1.29 (1.05 - 1.59) OR 1.16 (1.06 - 1.26) OR 1.32 (1.18 - 1.48) OR 1.15 (0.87 - 1.51)	Case-control, 9,313 cases. New York exposure analysis. Area is within one mile of New York hazwaste sites. Confounders investigated: race, maternal age, maternal education, pregnancy complications, sex, and previous live births. Indications of dose-response relationship. See Marshall.
(Shaw et al. 1992)*	Heart/circulatory CNS, MUS, oral clefts, skin, genitourinary Low birthweight	OR 1.5 (1.1 - 2.0) Not significant Not significant	Case-control, 5,046 birth defects. Area is census tract. Crude assessment of exposure. Confounders investigated included: maternal age, race, sex, and birth order.
(Sosniak, Kaye, and Gomez 1994)	Low birthweight, infant and fetal death, congenital malformation	Not significant	Case-control with 1,281 cases. Confounders investigated: smoking, drug use, family income, maternal age and education, and previous live births. Definition of congenital defects unclear. Area is one mile site to ZIP code centroid.
(Bove et al. 1995)*	Dichloroethylenes/ CNS Carbon tetrachloride/CNS Carbon tetrachloride /NTD Carbon tetrachloride/ low birthweight Benzene/NTD Trichloroethylene/ various	OR 2.52 (90% CI 1.25 - 5.09) OR 3.80 (90% CI 1.14 - 10.63) OR 5.39 (90% CI 1.12 - 18.95) OR 2.26 (90% CI 1.52 - 3.36) Not significant Not significant	Cited by Lybarger. Cross-sectional study of 75 New Jersey towns with contaminated ground water. 80,938 live births and 594 fetal deaths during 1985-1988. Monthly tap water surveys used for exposure analysis. Confounders analyzed include maternal age/race/sex, birth order, previous pregnancy complication, sex, and adequacy of prenatal care. Area not given.
(Berry and Bove 1997)	Low birthweight Preterm birth	OR 5.12 (2.14 - 12.27) OR 2.10 (1.01- 4.36)	Peak exposure periods only. 25 years of data. Confounders investigated: sex, birth order, maternal age, race, and education, and previous fetal deaths. Area is 1 km “downwind”.

Table 5.1 (Continued)

Study	**Health endpoints**	**Results (95% CI)**	**Notes**
(Marshall et al. 1997)*	CNS/proximity solvents	OR 1.3 (1.0 - 1.7)	Follow-up to Geschwind et al. Similar results found for associations of CNS birth defects with proximity to hazwaste sites, but more detailed analyses of specific compound/effect combinations with greater exposure specificity found no associations. Less than one half the number of observations as Geschwind et al. Area is within one mile of New York hazwaste sites.
	CNS/proximity metals	OR 1.4 (1.0 - 1.81)	
	CNS/exposure solvents	OR 0.8 (0.4 – 0.6)	
	CNS/exposure metals	OR 1.0 (0.7 - 1.7)	
	MUS/exposure solvents	OR 0.9 (0.5 - 1.3)	
	MUS/exposure metals	OR 0.8 (0.5 - 1.3)	
(Croen et al. 1997)	NTD	<¼miOR 2.1 (0.6 - 7.6)	Case-control with 507 NTD cases and 1,095 cardiac and cleft malformation cases. Confounders investigated included: maternal age,race, and education, maternal alcohol and tobacco use, maternal employment, household income, and neighborhood educational achievement. Area is ¼ and one mile to Superfund or hazwaste site.
	NTD/pesticides	<1mi OR 2.2 (0.9 - 5.2)	
	NTD/VOCs	<1mi OR 1.8 (0.9 - 3.4)	
	NTD/barium	<1mi OR 3.7 (1.2 - 9.8)	
	NTD/copper	<1mi OR 1.8 (1.1 - 5.2)	
	NTD/lead	<1mi OR 2.0 (0.9 - 4.1)	
	NTD/fluoranthene	<1mi OR 4.2 (1.1-12.4)	
	Heart defects	<¼miOR 4.2 (0.7-26.5)	
	Heart defects/chromium	<1mi OR 2.6 (0.9 - 7.4) .	
	Heart defects/lead	<1mi OR 2.3 (0.8 - 6.4)	
	Oral clefts	<1mi OR 1.2 (0.2 - 8.5)	
(Dolk et al. 1998)	Various congenital anomalies	OR 1.33 (1.11 - 1.59)	Confounders investigated: maternal age and socio-economic factors. Little heterogeneity across study sites. Case-control study with 1,089 cases but no detailed analysis of exposure. Area is within three km of 21 sites in Europe.
	NTD	OR 1.86 (1.24 - 2.79)	
	Malformed cardiac septa	OR 1.49 (1.09 – 2.04)	
	Great artery/vein malformations	OR 1.81 (1.02 – 3.02) .	
	Gastroschisis	OR 3.19 (0.95 – 10.77)	
(Orr et al. 2002)	Birth defects	OR 1.12 (0.98 - 1.27)	Multi-site, case-control study. Area is census tract with Superfund site.
	NTD	OR 1.54 (0.93 - 2.55)	
(Vrijheid et al. 2002)	Chromosomal congenital anomalies	OR 1.41 (1.00 - 1.99)	Anomalies include Down's Syndrome. No dose-response noted. 17 study areas with 23 hazwaste sites. Confounders investigated: maternal age and socioeconomic status. Area is within three km of 21 sites in Europe.

NOTES: * = The study had some direct measure of exposure and did not rely on proximity alone; OR = odds ratio; CNS = central nervous system defects; MUS = musculoskeletal system defects; NTD = neural tube defect.

Acute Accidents and Injuries

A considerable amount of data have been collected on acute accidents and injuries associated with hazardous substances. Some of these occur at schools, some at workplaces, and some are associated with releases. In many cases the first responders (e.g., fire, police) suffer potential or actual exposures to these materials, and first providers (e.g., hospital emergency staff) have also been exposed due to hazardous substances on the clothing or bodies of incoming patients. The Superfund program creates benefits by reducing the number of these exposures and by improving the capacity of various organizations to respond to them.

A considerable literature has been published on this topic, generally in journals associated with environmental health and emergency medicine. Table 5.2 summarizes some of this literature. The existence of a great majority of this information is directly attributable to work by ATSDR, which was created by CERCLA.

Table 5.2. Studies of Acute Accidents Associated with Hazardous Substances

Study	Effect Studied	Outcomes	Notes
(Binder 1989)	hazardous substance releases, injuries, deaths, and evacuations	587 releases resulted in death, injury or other event. 58 events resulted in 115 deaths; 496 resulted in 2254 injuries	Combined results from three systems (National Response Center, Hazardous Materials Information System, Acute Hazardous Events Database) indicated an average of 1.6 haz mat incidents per day resulting in death, injury or other.
(Hall et al. 1994)	hazardous substance releases, injuries, and deaths	1249 events in 5 states, 2 years; 204 resulted in 846 injured persons (1484 injuries) and 7 deaths	1990-91 HSEES included 200 priority substances; 5 participating states not selected randomly
(Hall et al. 1995)	hazardous substance releases, injuries, and deaths	1876 events in 9 states, 1 year; 263 resulted in 600 injured persons (1017 injuries) and 4 deaths	1992 HSEES included 200 priority substances; 1993 to include all haz subs except petroleum products and to include more states
(Hall et al. 1996)	hazardous substance releases, injuries, deaths, and evacuations	3125 events reported; 467 events resulted in 1446 injured persons (2501 injuries), 11 deaths	1990 - 1991: CO, IA, MI, NH, WI; 1992: CO, IA, NH, NY, NC, OR, RI, WA, WI
(Kales et al. 1997)	hazardous substances released and injuries produced in emergency responders	162 incidents, 47 of which caused injuries	respiratory symptoms most common; pesticides most often associated with victims; page 602 discussion addresses importance of preparedness and education
(Burgess et al. 2001)	incidence of acute health effects and persistent effects	various acute symptoms reported (Fig 1); 25% of subjects had symptoms persisting at least 8 days	acute symptoms included headache (40%), cough (33%), eye irritation (32%), throat irritation (32%), chest / lung irritation (26%), dizziness (25%), and nausea (20%)
(Berkowitz et al. 2002)	incidence of events with victims or evacuations following releases at schools	relative risk for event with victims = 3.94; avg # victims = 9 (compared with 4.3 in other industries); 393 events with 1053 victims	includes two "case reports" of children taking mercury from classrooms (page 20)
(Berkowitz, Barnhart, and Kaye 2003)	factors associated with severe injuries	2826 victims from 659 events; severe injuries assoc with explosions (aOR = 6.45) and other factors	limited to actual releases, manufacturing industry, fixed-facility; injury severity assoc with explosion (aOR = 6.45), multiple chemicals (1.75), multiple chem categories (1.70), acids (1.6), multiple injuries to individual (1.38-1.56), confinement within a structure (1.76-1.90), midwest facility location (1.76-1.90)

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Lead-Induced Health Effects

Many NPL sites are contaminated with lead and there has been considerable research into the effects of lead contamination and results of lead cleanups, both remedial actions and others. The table below summarizes some of the key studies.

Table 5.3. Studies of Lead Contamination and Cleanup

Study	Results
(Boon and Soltanpour 1992)	Samples of old silver mine dump materials, garden soils contaminated with mine dump materials, noncontaminated garden soils, and vegetation grown in these contaminated and noncontaminated gardens were collected near an NPL site in Aspen, Colorado. Many of the mine dump materials and soils contained sufficient quantities of lead and cadmium to pose potential health risks if the contaminated materials were ingested, especially by children.
(Weitzman et al. 1993; Weitzman, Aschengrau, and Bellinger 1993)	A study group whose homes got soil and interior dust abatement and loose paint removal experienced statistically significant declines in blood lead levels more rapidly than groups that got less or no intervention. When adjusted for preabatement lead level, the 11-month mean blood lead level was 1.28 µg/dL lower in the study group as compared with group A (p=0.02), and 1.49 µg/dL lower than in group B (p=0.01). The magnitude of the decline independently associated with soil abatement ranged from 0.8 to 1.6 µg/dL when the impact of potential confounders, such as water, dust, and paint lead levels, children's mouthing behaviors, and other characteristics was controlled for.
(Aschengrau et al. 1994)	Study in Boston of children with mildly elevated (<25 µg/dL) blood lead levels. Soil abatement of 2060 ppm was associated with a 2.25 to 2.70 µg/dL decline in children’s blood lead level, and the benefits of intervention were persistent (i.e., low levels of soil recontamination after one to two years). Remediation of lead-based-paint hazard was less effective.
(Kimbrough, Levois, and Webb 1995)	Soil lead and blood lead levels near a closed smelter in Granite City, Illinois were investigated, including an 827-person survey. Based on multiple regression modeling, lead in house dust accounted for 18% of the variance in blood lead levels. Lead in paint and condition of the house were the main contributors to the dust lead variance (26%), with soil lead accounting for an additional 6%. Factors such as education of parents, household income, and behavior were associated.
(Maisonet, Bove, and Kaye 1997)	Results suggest that removal of lead-contaminated soil from residential yards was effective in reducing blood lead levels in children. Of the variables examined, yard soil remedial action showed the strongest association with changes in blood lead levels. Yard soil remedial action was found to be a statistically significant protective factor for elevated blood lead levels in children.
(Farrell et al. 1998)	A study of abatement of moderate soil lead contamination (reductions of about 470 ppm) in Baltimore, Maryland showed little effect on blood lead levels. Soil abatement is clearly less important than addressing the problem of lead-based paint in this setting.
(Mielke et al. 1999)	Large-scale assessment in New Orleans, Louisiana showed a strong association between soil lead and blood lead concentrations. Higher soil lead concentrations appear to be primarily due to localized deposits from leaded gasoline combustion, and are associated with lower income, residence in rental housing, and minority populations.
(Lewin, Sarasua, and Jones 1999)	A multivariate linear regression model was used to find a slope factor relating soil lead levels to blood lead levels. Previously collected data were used from the Agency for Toxic Substances and Disease Registry's (ATSDR's) multisite lead and cadmium study, including the blood lead measurements of 1015 children aged 6-71 months, and corresponding household-specific environmental samples. The environmental samples included lead in soil (18.1-9980 mg/kg) and other media. After adjusting for income, education of the parents, presence of a smoker in the household, sex, and dust lead, the predicted blood lead level corresponding to a soil lead level of 500 mg/kg was 5.99 µg/kg with a 95% prediction interval of 2.08-17.29. Predicted values from this regression model are subject to high levels of uncertainty and variability.

Table 5.3 (Continued)

Study	Results
(Brown 2002)	A decision analysis using population-based data of childhood lead exposure showed that strict enforcement of housing policies to prevent childhood blood lead elevation results in decreased societal costs due to the avoidance of future medical problems and special education needs, as well as increased productivity of resident children.
(Johnson and Bretsch 2002)	A study combined over 12,000 blood lead level screenings in Syracuse, New York with spatially detailed soil lead monitoring, and showed that when soil lead data are aggregated across spatial units of sufficient scale, strong associations are observed between blood lead levels and soil lead values. $R^2>0.65$ for the regression of GM blood lead level on median soil lead. Large samples appear necessary to detect this effect.
(Khoury and Diamond 2003)	Two models (ICRP and IEUBK) were used to estimate blood lead levels in children near a closed lead smelter in Dallas, Texas. Remedial and removal activities were found not to cause significant long-term or acute risk, or significant recontamination of remediated residential yards.
(Lanphear et al. 2003)	Soil abatement was associated with a significant decline in children's blood lead level. Blood lead levels in children aged 6-72 months who lived in soil-abated housing declined 42.8% faster than children who lived in unabated housing (p=0.14). In children aged 6-36 months, the decline was 45.4% faster (p=0.03). The reduction in blood lead levels in children aged 6-36 months was 3.5 µg/dL for every 1000 ppm reduction in soil lead (95% CI: 2.4-4.6).
(Lorenzana et al. 2003)	This article presents the results of a survey of the publicly available literature on the effectiveness of lead intervention on pediatric blood lead levels at six hazardous waste sites located in Canada, Australia, and the United States. Evaluation is often complicated due to confounding variables and statistical limitations. Nevertheless, the intervention studies reviewed in this report suggest that various approaches to the intervention of the dust ingestion pathway, alone or in combination, contributed to declines in blood lead levels in children living in areas heavily contaminated with lead.
(Sheldrake and Stifelman 2003)	A review of cleanup effectiveness at the Bunker Hill NPL site has shown that yard soil cleanup is an effective tool for reducing house dust lead concentrations, and thereby reducing children's blood lead levels. This review has also shown that contiguous cleanup of residences has a three-fold greater reduction of children's blood lead levels compared with cleaning only those homes where children currently reside by reducing exposures attributable to neighboring properties.
(von Lindern, Spalinger, Petroysan et al. 2003)	A comprehensive survey of lead exposure and health effects at the Bunker Hill NPL site showed that soil remedial action without "intervention" (parental education) reduced blood lead levels in two-year-olds by 7.5 µg/dL over 10 years. Those receiving intervention had an additional 2-15 µg/dL decrease. Correlations between local contamination and blood lead levels were observed: they increased 0.9 µg/dL per 1000 mg/kg house dust lead and 4.0 µg/dL per 1000 mg/kg lead in soil.
(Lidsky and Schneider 2004)	A total of 48 papers are reviewed with respect to reconsidering the 1991 recommendations by the CDC that children's blood lead level be controlled down to 10 µg/dL. Experimental and clinical bodies of literature are covered. The experimental studies show that even at low blood lead levels, brain cells in children may be exposed to concentrations at which several fundamental cellular processes are negatively affected (e.g., activity of the protein synaptotagmin I, which is active in signaling between brain cells). The clinical studies are consistent in showing detrimental effects on IQ and other measures of neuropsychological functioning at levels below 10 µg/dL. This research indicates that similar exposures manifest themselves differently in individual children. Lead-based paint is the primary source of lead poisoning for children with mildly elevated (<25 µg/dL) blood lead levels.

The studies in Table 5.3 support several relevant observations. First, a variety of significant negative health outcomes can result from even relatively low levels of childhood lead exposure. Second, while most childhood lead exposures in the United States are due to lead-based paint and soil contamination from pre-1980 gasoline exhaust, wastes near some former mining and smelting operations that are now NPL sites can cause significant exposures. Third, responses at NPL sites have been shown to significantly reduce blood lead levels in children living nearby without causing additional exposures.

There is also some evidence that some disease conditions in adults are linked to lead exposure, including high blood pressure, stroke, coronary heart disease, renal disorders, anemia, and reproductive abnormalities including miscarriage and increased infant mortality due to maternal exposure (Preuss 1993). However, because it is difficult to attribute these health effects solely to lead exposure, this study only evaluates lead-based health effects caused by lead exposure to children less than five years old.

Data obtained from ATSDR show that at least 120 NPL sites had completed exposure pathways for lead, all of which have been designated either an “Urgent Health Hazard” or “Public Health Hazard.” Thus, health benefits from Superfund response actions can be expected at these sites.

This study will quantify and monetize three benefits due to such interventions: elimination of the need for medical exams and testing for lead-exposed children, reduced excess costs associated with special education for students with learning disabilities related to lead exposure, and elimination of the wage gap due to lower intelligence caused by childhood lead exposure. The wage gap results from both lower education attainment and from lower labor force participation.

The EPA Integrated Exposure Uptake Biokinetic (IEUBK) model is proposed for this analysis, similar to applications found in the literature (Khoury and Diamond 2003; von Lindern, Spalinger, Petroysan et al. 2003). The IEUBK calculates the intake and absorption of lead by children of different ages.[5] The model is designed to provide an expected mean blood lead level in a population of similarly exposed children, not to predict the blood lead level of any individual child. Lead concentration data from CERCLIS and ATSDR HazDat databases, and population data from the U.S. Census will be used for sites at which CEPs for lead exist. The IEUBK model will be used to determine each site’s population’s geometric mean blood lead level (BLL) and the percent of children whose BLL exceeds 25 µg/dL. However, because the IEUBK model has not been validated for blood lead levels above 30 µg/dL, the study will use the blood lead level of 30 µg/dL as a conservative estimate for any BLL that exceeds the 30 µg/dL threshold.

To determine the health conditions expected at different blood lead levels, two previous EPA reports will be relied upon (U.S. Environmental Protection Agency 1999, 1996) These reports assume that any increase in blood lead level above 0 µg/dL causes a decrease in intelligence, as measured by IQ. The IQ decrement was assessed at 0.245 points per µg/dL of blood lead, with no lower threshold. However, IQ decrements and other health effects do not appear to be well quantified for very low BLLs. Thus, the proposed method would include an assumption that Superfund responses would reduce childhood BLLs from the levels predicted by the IEUBK model to the current CDC standard of 10 µg/dL and that there are no effects below this level.

In addition to the decreased intelligence experienced by all children exposed to lead, children with blood lead levels exceeding 25 µg/dL require additional services, including medical care and testing and special education assistance to compensate for learning disabilities or behavioral

[5] Intake and absorption measures include dust lead loading that occurs at each soil lead level, the amount of water that children are likely to drink, the respiration rate of children of different ages, and the relative absorption of lead from each media of exposure. The IEUBK model is available at: www.epa.gov/superfund/programs/lead/ieubk.htm.

problems. The number of such children will be calculated and estimates of the treatment and other costs will be taken from the EPA's *Cost of Illness Handbook* (U.S. Environmental Protection Agency 2002).

This study will not include some potential benefits of lead remediation because there is insufficiently strong evidence to quantitatively link lead response actions at NPL sites with possible beneficial outcomes. An example includes possible reductions in levels of violence. Children exposed to lead often demonstrate antisocial behavior, poor impulse controls, and aggressive tendencies. One study compared convicted juvenile offenders to non-delinquent controls in Alleghany County, Pennsylvania (Needleman et al. 1996). Bone lead levels in the tibia were measured in subjects between the ages of 7 and 11 years old. Juvenile offenders, regardless of race, had higher mean bone lead concentrations than the non-delinquent controls. Another study compared air lead concentrations and blood lead levels in all counties in the contiguous 48 states (Stretesky and Lynch 2001). The incidence of homicides was nearly four times higher in counties with the highest air lead levels compared to counties with no air lead contamination. After adjusting for other sociological and air pollution factors, air lead concentration was the only factor associated with homicide rates. The potential benefits realized from reducing lead exposures could be substantial, with a 1998 study estimated that helping one high-risk youth avoid a life of crime provides $1.5-2 million in societal benefits (Cohen 1988). However, for the reasons noted above, these effects will not be included here.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

Cancer and Other Risks

A small number of studies have evaluated cancer and other (non-birth defect) risks related to hazardous substances in the environment. These are summarized in Table 5.4.

Table 5.4. Studies of Cancer and Other Health Effects

Study	**Effect Studies**	**Outcomes**	**Notes**
(White et al. 1997)*	Neurological effects (facial numbness, sensory impairment, peripheral neuropathy, reflex abnormalities)	Diagnosis of mild to moderate encephalopathy in over 80%. 75% of children had major behavioral difficulties.	Clinical study of trichloroethylene (TCE) in drinking water (mostly wells). No area given.
(Hamilton and Viscusi 1999)*	Cancer	Seven cases/site (mean, scenario 2, 30 yrs) but most sites have <0.1	Data from detailed review and analysis of 99 sites, using mean concentration values. Authors note data for noncancer risk may be provided by then-ongoing ATSDR research. Area is four miles from NPL site.
(Costas, Knorr, and Condon 2002)*	Childhood leukemia - Not exposed in utero - Least exposed in utero - Most exposed in utero	Significant dose-response, 95% OR 1.00 OR 3.53 (0.22 - 58.1) OR 14.3 (0.92 – 224.5)	Case-control with 19 cases in Woburn, Massachusetts. Detailed water contamination modeling. Confounders investigated included maternal alcohol consumption. Significant association with breast feeding was found. No area given.
(Jarup et al. 2002)	Cancers: bladder, brain, hepatobiliary leukemia	No excess risk	80% of the population of Great Britain lives within two km of a landfill, so 80% of the population was considered 'exposed'. Same results even when they looked at hazwaste landfills. Area is within two km of 9,565 landfills in Great Britain
(Carpenter et al. 2001)	Thyroid dysfunction Ovarian dysfunction Testicular dysfunction Female genital tract	Significant in females No significant increase No significant increase Significant increase	Hospitalization records. Peak increases: female thyroid ~65% (age 35-44), female genital tract ~40% (age 35-44). Area is ZIP codes within 15 miles of three Areas of Concern in New York State.

NOTES: * = The study had some direct measure of exposure and did not rely on proximity alone; OR = odds ratio.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

Ecological

Overview

Like many environmental policies, Superfund seeks to protect and restore the environment as well as protect human health. Because uncontrolled releases of hazardous substances can significantly injure ecological systems, Superfund legislation contains several provisions that address ecological impacts. Although ecosystems have a profound impact upon human well-being, the quantitative assessment of ecological benefits presents a formidable challenge for several reasons.[6] First, natural systems are inherently complex. Knowledge about the many services they provide and how they provide them is sparse. Moreover, conclusions about site-specific impacts are subject to considerable uncertainty. Second, ecological risks vary widely in terms of persistence, geographic extent, and the degree to which the overall threat can be predicted. For instance, uncontrolled releases of hazardous substances include one-time spills of chemicals into rivers as well as long-term conditions like acid mine drainage, which can have very different ecological outcomes. Third, many of the less tangible benefits are not readily amenable to monetary valuation.

This section provides a general discussion on the literature of ecological effects, measuring ecological benefits, the NRDA process and literature, and estimating benefits for NRDAs.

Literature of Ecological Effects

EPA's guidelines for ecological risk assessment require that ecological risk assessments (ERAs) be conducted at every response according to a well-established, consistent process (Luftig 1999; U.S. Environmental Protection Agency 1998). However, natural resource damages play a relatively small role in Superfund responses compared to health risks (Walker, Sadowitz, and Graham 1995, 29; Suter et al. 2000, chapter 8). Further, the problems of lack of readily accessible information and inappropriate assumptions for a benefits estimation that plague health risk assessments of Superfund sites also apply to ERAs. Searches in the published and gray literature for quantitative estimates of the ecological risks addressed by Superfund responses yielded no results.[7] Thus, there is little data available about improvements in ecological conditions due to Superfund responses. Nonetheless, Superfund responses may create ecological benefits by reducing the amount and type of hazardous substances to which wildlife are exposed, as illustrated by the LCP Chemicals case study on page 3-10.

At LCP Chemicals, EPA's rapid response to Georgia's request for assistance greatly reduced the site's environmental risks. The removal action carried out at the site resulted in lowered levels of PCBs and mercury in the site's aquatic species. Before the removal action, the Georgia Department of Natural Resources advised against consuming a species of fish (red drum) from Purvis Creek, which is near the site. Data collected after the removal action show that it is now safe to eat red drum once a week. These ecological improvements created by removal actions may be similar to the changes caused by natural resource restorations in the Lower Fox River, even though at LCP Chemicals the improvements were caused by responses designed to achieve health risk reduction goals, not natural resource restoration goals.

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[6] Some of this text as well as the accompanying figure are adapted from (U.S. Environmental Protection Agency 2000, 69-71).

[7] This search included the use of multiple electronic tools including online search engines, EPA's websites, and various databases such as EconLit and Web of Knowledge.

Provisions of CERCLA (42 U.S.C. 9601(16)) authorize and require federal and state agencies to mitigate harmful effects of releases on ecological systems.[8] The general term for these injuries is natural resource damages (NRD).[9] The analysis of the size and scope of these injuries is called natural resource damage assessment (NRDA). Natural resources are defined by CERCLA to provide fairly broad coverage under sec. 9601 as land, ground water, habitat, fish and other wildlife, and other resources owned, managed, held in trust, or otherwise controlled by the United States, any state or Indian tribe, or any foreign government. Natural resources can also be viewed as assets that provide flows of services over time to other natural resources and to people. When natural resources are damaged, the flows of ecological and human services provided by those natural resources (and thus the values they provide) may be interrupted for some time. Thus, the public incurs interim losses from the damage.

EPA's chief role with respect to NRDs under the Superfund legislation, is one of notification and coordination. The law requires the President to designate federal officials who shall act on behalf of the public as trustees for natural resources; these trustees include the Secretaries of Agriculture, Commerce, Interior, and others. Under the provisions of CERCLA and SARA, EPA notifies trustees of potential injuries to natural resources at sites where releases or threats of releases are under investigation, notifies trustees of relevant negotiations with potentially responsible parties (PRPs), encourages the participation of trustees in these negotiations, and coordinates various assessment and planning activities with trustees. The major role of the trustees under CERCLA is to conduct NRDAs and recover costs beyond cleanup to restore or replace natural resources to the conditions that would have existed without the hazardous substance release. The value of the injured resources is often calculated in NRDAs in order to facilitate this effort.

Sites at which NRDs occur are not necessarily associated with the National Priorities List (NPL), although many are. EPA is required to, and does, coordinate with the natural resource trustees who implement the NRD provisions of Superfund (Office of Solid Waste and Emergency Response 1992). Some NRDs are extensive and result in lawsuits seeking very large (>$10 million) settlements from responsible parties. These large cases may be studied extensively, resulting in significant NRDA reports that present an opportunity to gain some insight into the ecological benefits of Superfund (e.g., Stratus Consulting 2000; Morey et al. 2002). There are two opportunities. First, any benefits that are created by natural resource restoration can be attributed to Superfund because it is provisions of CERLA and SARA that lead to the restoration. Second, because most sites that are the subject of NRDAs are also NPL sites, this provides some insight into the potential ecological benefits of Superfund response actions. Specifically, that is because some of these response actions may include activities similar to some of those undertaken in natural resource restorations, or at least have similar impacts on wildlife.

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[8] Pursuant to Executive Order 12316 those authorities were delegated by the President to the various trustee agencies (e.g., the Departments of Agriculture, Commerce, and Interior) and not to EPA. In addition, ecological restoration is not permitted nor undertaken with Trust Fund monies. The Clean Water Act and Oil Pollution Act contain similar provisions, but these are ignored here.

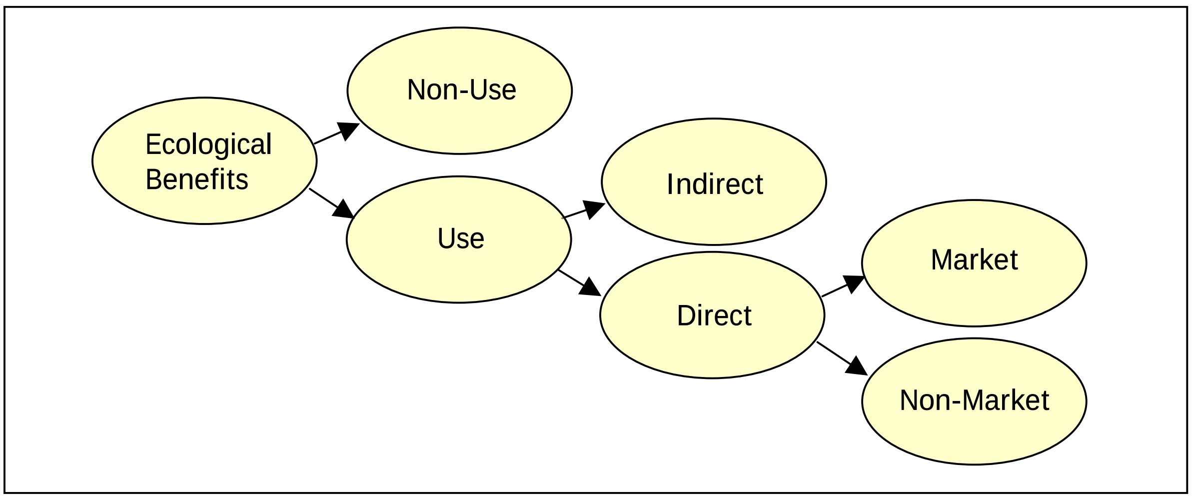
[9] In a legal sense, "damages" refers to monies that are recoverable in a lawsuit as compensation for interrupted flows of ecological services, not the physical harms, which are called injuries. As discussed in more detail below, the magnitude of damages calculated in NRDs are also not equal to the magnitude of the benefits of restoration.

Measuring Ecological Benefits
In general, ecological benefits may be thought of as flows of services from the natural asset in question. These can be categorized by how directly they are experienced. Figure 5.1 illustrates how the categories relate to one another, and how valuation techniques differ.

Direct market benefits are some of the most readily identified service flows provided by ecosystems. These typically relate to primary products that can be bought and sold competitively, either as factors of production or as final consumption products. Relevant examples include commercial fish species, which can be harmed by uncontrolled releases of hazardous substances into aquatic ecosystems. When access is controlled and appropriate user charges levied, recreational opportunities may also be considered direct market benefits, which may be reduced by degradation due to uncontrolled releases.

Non-market benefits include recreational opportunities and aesthetic qualities provided by ecosystems. These are also experienced directly by individuals, but typically do not have a market value associated with them directly. Non-market benefits can include both consumptive uses (e.g., recreational fishing and hunting) and non-consumptive uses (e.g., scenic vistas, wildlife viewing, hiking, and boating). These services are typically provided by natural assets held in common (e.g., public lands). They have public goods characteristics since access is not or cannot be controlled, and consumption is not exclusive.

Figure 5.1. Classification of Ecological Benefits



Source: U.S. Environmental Protection Agency 2000.

Indirect benefits are derived from ecosystem services that do not directly provide a good or opportunity to individuals, yet are valued because they support off-site ecological resources or maintain the biological and biochemical processes required for life support. These indirect benefits tend to be purely public in nature -- access to or use of the service is not exclusive and a virtually unlimited number of individuals can share in the benefits without reducing the average benefit accruing to each. Each type of ecosystem provides various indirect benefits. Wetlands recharge ground water, mitigate flooding, and trap sediments. Rivers provide spawning locations for anadramous fish. Terrestrial ecosystems provide habitat for natural pollinators. All of these systems support biodiversity.

Finally, non-use benefits are those that are not associated with any direct or indirect use by individuals or society. Rather, non-use benefits arise when people value an ecological resource without using it. Non-use values are often referred to as passive use values in the legal literature, and are those associated with, for example, knowledge that the resource could be used by the individual making the valuation (sometimes called *option value*), knowledge that the resource exists in an undisturbed state (sometimes called *existence value*), and knowledge that future generations will be able to use the resource (sometimes called *bequest value*).

Once the types of service flows associated with a natural resource have been identified, the next step in the analysis of ecological benefits is to estimate the physical effects of each policy option, comparing the flow of services with and without the policy. Ecologists and environmental toxicologists conduct ecological risk assessments to estimate expected adverse ecological effects. Environmental economists are typically then called upon to estimate the value of these effects.

Economists have developed a number of methodologies to measure the benefits of changes in the environment. Market methods can be used when direct markets for environmental goods and services exist. The benefits of a change in quantity of a good are estimated using data on these market transactions. Unfortunately, direct markets for environmental goods and services do not often exist. Revealed preference methods (or *indirect approaches*) allow economists to infer the value placed on environmental goods using data on actual choices made by individuals in related markets. Revealed preference methods include recreational demand models, hedonic wage and property models (the latter being approach used in Chapter 5), and averting behavior models. Stated preference methods (or *direct approaches*) allow economists to estimate the value placed on environmental goods using data on hypothetical choices made by individuals responding to a survey. Stated preference methods include contingent valuation methods (CVM), conjoint analysis, and contingent ranking.

For site-specific ecological benefits, the process of estimating the value of changes in the environment can take several years and cost several million dollars. Therefore, due to resource limitations, this study uses existing NRDAs and ground water studies to estimate the size of the ecological benefits of the Superfund program. This will yield only a rough underestimate

The NRDA Process and Literature

Over the last several decades, the number and quality of studies of natural resource damages has increased significantly. This includes both theoretical advances and practical applications. Some of this literature is summarized and theoretical issues are discussed in (Damage Assessment and Restoration Program (DARP) 2004; Reisch 2001; Barnthouse and Stahl 2002; Ofiara 2002; Deis and French 1998; Kopp and Smith 1989). Many of the methods and procedures for estimating the NRDs have been created through a combined legal-economic framework that has established the use of CVM methods in the context of specific cases and more generally (General Electric v. U.S. Department of Commerce (NOAA) 1997; National Association of Manufacturers v. U.S. Department of Interior 1998; Ohio v. Department of Interior 1989; Arrow et al. 1993).

Most NRDAs have been performed in conjunction with lawsuits and many of them appear to be unavailable publicly. However, data and results from some NRDAs have been published in one form or another.

The earliest NRDAs date from the late 1980s, such as a study of mining-damaged areas in Colorado (Kopp and Smith 1989a, 1989b). Other early NRDA studies included one that evaluated a large pesticide spill off the California coast (Carson et al. 1994). These NRDAs examined cases at or associated with NPL sites, but the damage estimates are not related to the response actions at those sites.

Some NRDAs are conducted for large spills of hazardous substances (Desvousges and Dunford 1992; Loomis and Anderson 1992; Stopher 2000; U.S. Fish and Wildlife Service Region 5 Virginia Field Office 2002). These sites are typically not NPL sites, and may not be eligible to become NPL sites, but they may be sites at which a removal action takes place. However, Section 9601 of CERCLA applies to these spills and trustees can recover damages in order to restore the environment. Some spills can result in sizeable damages. For instance, the Cantara Loop spill in California resulted in one of the largest NRDA settlements to date, $38 million, which is being used to support a number of restoration projects (Sheey et al. 2000).

NRDAs may or may not estimate the monetary value of ecological benefits. As mentioned above, no existing studies that attempt to value the ecological benefits of responses and/or restorations could be found in the peer-reviewed literature or in the gray literature. And while ecological risk assessment is becoming more widely practiced, it is not clear that the results of these assessments would be useful for the calculation of benefits (U.S. Environmental Protection Agency 1998; Pastorok, Shields, and Sexton 2002; Mathews, Gribben, and Desvousges 2002). However, remedial actions can have significant ecological benefits, as the case study of LCP Chemicals (p. 3-10) illustrates.

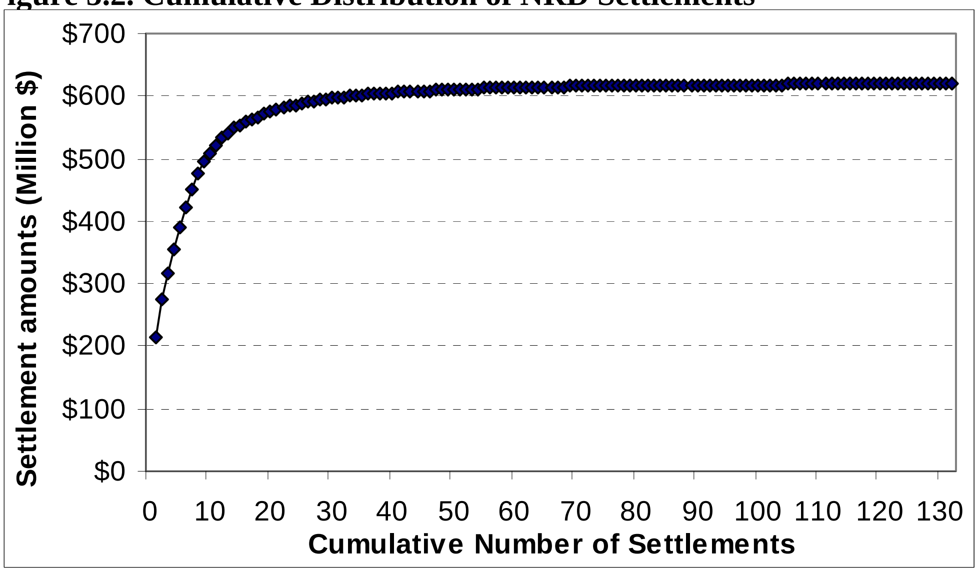
All NRDAs calculate damages, which in the context of NRDs are defined as injury to, destruction of, or loss of natural resources and are measured as the cost of restoring injured natural resources to their baseline condition, compensation for the interim loss of injured resources pending recovery, and the reasonable costs of a damage assessment. However, NRDAs are usually conducted as part of litigation, and some may never be available for public inspection. Others are accessible only by obtaining court documents, which have not been located for this study. A search was conducted to find information about NRDAs that is readily accessible. Over 130 NRDAs were found for which a settlement amount was identified. Table 5.5 contains part of this inventory and Figure 5.2 shows the cumulative distribution of these settlement amounts.

Settlements are arrived at through jury decisions or negotiated consent decrees, and may include many factors not included in economic analysis. Thus settlement amounts may not be very good indicators of benefits, but they are somewhat illustrative of the size of the NRD. The mean settlement amount in the inventory is $4.7 million, but the median value is only $0.18 million. Thus, a small number of NRD cases account for a large portion of the total value of settlements; the 12 settlements that are over $10 million represent about 10% of all cases but more than 85%

of the total settlement value. Of the 130 NRD settlements, 70 (or about half) are indicated as being associated with NPL sites, including almost all the larger settlements.

Table 5.5 contains information on several of the larger NRD settlements, and a small selection of the remainder. It illustrates the type of information that is readily available, from almost none (e.g., Kennecott) to very detailed (e.g., Lower Fox River). The table also shows there are some well-known NPL sites that also have NRD settlements associated with them (e.g., Times Beach). Table 5.5 also provides an indication of the very large range of settlement amounts (over four orders of magnitude). While it is not possible to make a quantitative comparison, this very large range suggests that the size of potential benefits created by natural resource restoration could also vary a great deal. Finally, this table shows that the actual natural resource damages are more than twice as large as the settlement amounts, however, the number of cases where this comparison can be made is very small.

Figure 5.2. Cumulative Distribution of NRD Settlements



Note: For illustrative purposes only. Settlement amounts do not correspond to benefits.

Table 5.5. Natural Resource Damage Cases

Site Name	State	NRDA Amount (Millions$)	Settlement Amount (Millions$)	Site Size	Site Type	Notes (Trustee Info, Contamination)
Clark Fork River	MT	764	215	26 riparian miles	NPL	Mining, smelting, industrial, & municipal wastes; vast mine tailings deposits along the creek; metals; waterfowl deaths; Trustees: State of Montana, Confederated Salish & Kootenai Tribes, DOI
Blackbird Mine	ID	-	60	830 acres	NPL	Acid mine drainage potentially affects two rare species of salmon; Trustees: NOAA, State of Idaho, US Forest Service
Lower Fox River	WI	86.8	41.5	-	NPL	PCBs; Trustee: FWS
Cantara Loop	CA	-	38	36 riparian miles	Non-NPL	Chemical spill (19,000 gallons of herbicide); Trustees: CA Dept. of Fish & Game; Central Valley Regional Water Quality Control Board; US FWS
Kennecott	UT	-	37	-	NPL	-
Montrose Settlements	CA	-	30	13 acres	NPL	DDT, PCB
New Bedford Harbor	MA	-	20.2	18,000 acres	NPL	PCBs; Trustees: NOAA, DOI, Commonwealth of Massachusetts
NYC Landfills	NY	-	8	-	-	-
Idarado	CO	-	5.35	-	Non-NPL	-
Tar Creek	OK	-	0.72	40 sq. mi.	NPL	Acid mine drainage with heavy metals; Trustees: FWS, State of Oklahoma
Times Beach	MO	-	0.37	8 sq. mi.	NPL	Dioxin
John Day River Acid Spill	OR	-	0.28	-	-	Trustees: FWS, State of Oregon, Confederated Tribes of the Umatilla Indian Reservation
Fort Wayne Reduction Dump	IN	-	.005	35 acres	NPL	VOCs, heavy metals, & PCBs in site soils
Volney Landfill	NY	-	.0065	85 acres	NPL	VOCs & heavy metals in ground water

Sources: See text

Although fairly little information is readily accessible about most NRDs, it may be possible to use those for which more information has been published to estimate the ecological benefits of the natural resource restoration. Probably the best-documented case is the Lower Fox River, which will be used in the following sections to illustrate how information from NRDAs can be used to estimate benefits (Lazo 2002; Stratus Consulting 2000). The Lower Fox River flows thorough parts of Wisconsin and empties into Green Bay on Lake Michigan. It has been contaminated with polychlorinated biphenyls (PCBs) that have harmed fish populations and other natural resources. This contamination has resulted in advisories against eating fish or fowl from these areas. In the environment, PCBs decompose over time, so eventually the Lower Fox River and Green Bay would be expected to return to a more natural condition. However, this process could take many decades.

The NRDA for the Lower Fox River extends over almost 700 pages and includes estimates of the nature and extent of harmful effect to the ecosystem as well as the value of the loss of various service flows through CVM techniques (Stratus Consulting 2000; Breffle et al. 2005). This study is the largest, most comprehensive, and one of the highest quality NRDAs available. It estimates a partial WTP for residents of ten Wisconsin counties (Michigan residents are ignored) for various restoration plans. For instance, the total WTP for restoration of the ecosystem in 20 years rather than waiting for natural processes to restore it over the course of a century is $356 million (Stratus Consulting 2000, 6-10). This is only one estimate of many and depends on assumptions about the rate of natural decomposition of PCBs, which is uncertain.

Case Study: Kennecott

Some of the largest and most complex NPL sites are former mines. For instance, metal ores, primarily copper, have been mined and smelted in the Oquirrh Mountains west of Salt Lake City for over one hundred years.[1] The Kennecott Utah Copper Corporation (Kennecott) conducts most of the mining in the Salt Lake City area, as close as 25 miles to the city. Mining activities at the South Zone began in the 1860s and continue to the present day at the Bingham Canyon open-pit mine. Historically, mining operations produced lead, zinc, silver, copper, molybdenum, and gold ores. For much of that time, environmental safeguards were unheard of, so early miners deposited mining wastes in creeks, floodplains, and valley slopes. These wastes have eroded and washed downstream. Therefore, it comes as no surprise that the streams, soils, and groundwater of the area became heavily contaminated.

Kennecott's contaminated property is a strong candidate for inclusion on the National Priorities List (NPL) and was proposed for the NPL in 1994, but EPA, working in cooperation with representatives of the state as well as Kennecott, chose to allow a private cleanup with joint federal and state oversight. This case study illustrates how EPA can creatively use its authority under Superfund to encourage voluntary cleanups without engaging in the NPL process. At sites such as Kennecott, this approach can result in a less expensive and contentious cleanup that meets stringent EPA environmental and health standards. A combination of factors is motivating Kennecott to work with EPA and state agencies to clean up its land. Because Kennecott felt certain that an NPL cleanup would be far more expensive, EPA was able to use the threat of NPL listing to motivate cooperation. Also, Kennecott's lands are on the fringe of the rapidly growing Salt Lake City metropolis. By cleaning up its property, Kennecott can parlay exhausted mine lands into valuable real estate developments. Lastly, by taking responsibility for its actions and voluntarily cleaning up its property, Kennecott is able to restore and preserve its good reputation with the people of the Salt Lake area.

The Kennecott site includes most of the mining area in the Oquirrh Mountains, the western boundary of the Salt Lake Valley. The huge site area – dozens of square miles – is divided into a South Zone, where ores are mined and concentrated, and a North Zone, where ores are processed and smelted. Ore and tailings mined in the South Zone are sent to the North Zone, 20 miles away, by slurry and rail. The site encompasses a number of communities, including Copperton, Herriman, South Jordan, Riverton, West Jordan, and Magna.

Contaminants found in the South Zone include arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. In the past, before the threat was recognized, homes were built on former flood plains contaminated with high levels of lead and arsenic. Drinking water wells contaminated with cadmium, chromium, and arsenic had to be shut down. Mining wastes have leached acid waters and created a 72-square-mile plume of sulfate-contaminated ground water, forcing a moratorium on well-drilling in the area. The ground water plume has precluded some communities from using the ground water as a municipal water supply, which would otherwise be their primary and least expensive source of drinking water.

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[1] Most of the information used to create this case study was obtained from various documents available on the Internet in February-August 2004. These sources include the following: ATSDR's Public Health Assessment for Kennecott (South Zone), undated, available online at http://www.atsdr.cdc.gov/HAC/PHA; EPA's NPL Site Narrative for Kennecott South Zone, 1994, www.epa.gov/superfund/sites/npl/nar1428.htm; EPA's Fact Sheet for Kennecott South Zone, 2003, www.epa.gov/region8/superfund/sites/ut/kennes.html; EPA's Fact Sheet for Kennecott North Zone, 2003, www.epa.gov/region8/superfund/sites/ut/kennn.html; ATSDR's Public Health Assessment for Kennecott (North Zone), undated, www.atsdr.cdc.gov/HAC/PHA/; http://www.daybreakutah.com/masterplan.shtml. Information was also obtained through a personal interview with Jon Callender of Kennecott Land on June 3, 2004.

Kennecott, and to a lesser extent, ARCO (the Atlantic Richfield Company) are conducting cleanup activities at the South Zone with oversight by state and federal agencies. Removal of the surface wastes was completed in 1999. More than 25 million tons of lead- and arsenic-contaminated mining wastes were removed. The University of Cincinnati conducted a study in 1993 of children under the age of six living in the Bingham Creek area of Kennecott's South Zone. Of the 1,706 eligible children, 971 participated in the investigation, which included an analysis of lead concentrations in the children's blood and arsenic levels in their urine. The study found that two of 284 children from contaminated areas had blood lead levels above 10 µg/L (the level the Centers for Disease Control and Prevention defines as elevated). One child had urine arsenic levels above 20 µg/L. The Agency for Toxic Substances and Disease (ATSDR) conducted a Public Health Assessment (PHA) for the South Zone and analyzed data from the University of Cincinnati study. The agency concluded that before removal of contaminated soil from residential property in the Bingham Creek flood plain, exposure to lead and arsenic may have resulted in a moderate increase in the lifetime risk of cancer. However, the PHA also determined that the subsequent removal of highly contaminated soil near Bingham Creek eliminated a public health hazard. The PHA also points out that children under six in another area of the South Zone, Butterfield Creek, could have adverse health effects from lead in soil if they were exposed to it on a regular basis. The Assessment found that soil lead levels of 1,000 mg/kg could increase lead levels in blood from 0.7 to 68 µg/dL with an average increase of 4 to 5 µg/dL. The health effects of such an increase would depend on the existing burden of lead in the body. The PHA concluded that residents on 30 properties at Butterfield Creek may have been exposed to high levels of lead and arsenic and that this health hazard will not be eliminated until the removal of contaminated soil there is complete.

The long-term remediation of contaminated ground water at the South Zone is underway. ATSDR's Public Health Assessment for the South Zone states that ground water monitoring and Kennecott's provision of alternate water supplies have greatly reduced the potential for exposure to sulfate-contaminated ground water.

Kennecott's North Zone is situated at the north end of the Oquirrh Mountains, on the south shore of the Great Salt Lake. Metal ores have been smelted and processed here for almost one hundred years, resulting in contaminated sludge, soil, surface water, and ground water. Lead, arsenic, and selenium are the main contaminants of concern. A plume of selenium-contaminated ground water is entering nearby wetlands through springs and seeps; this is a cause for concern because birds are particularly sensitive to selenium. Kennecott, as the primary landowner and only responsible party at the North Zone, is solely responsible for the area's cleanup.

Removal of the North Zone's surface wastes was completed in 2001. Sludges produced by the treatment of processing waters from the refinery and smelter were excavated and deposited in an on-site repository, along with contaminated soils found during the modernization of the smelter and refinery. The Kennecott site remediation provides another example of EPA's ability to address complex environmental problems with innovative approaches. To treat the groundwater plume, microbes that reduce selenium contamination will be injected into the aquifer.

In addition to the "stick" of potential NPL listing, there is also a "carrot" motivating Kennecott's cleanup activities. Salt Lake City's rapid growth has created lucrative development opportunities for Kennecott, which is a major landholder in the Salt Lake City suburbs. Kennecott's first major real estate development is Daybreak, a master-planned community in South Jordan slated to contain over 13,000 homes and millions of square feet of retail, office, and industrial space. Kennecott understands that cleaning up its property is an essential step in transforming depleted minelands into valuable real estate development opportunities.

Although the Kennecott site was never listed on the Superfund National Priorities List, its cleanup can be considered a major accomplishment of the Superfund program and law. The threat of NPL listing, with the additional expense and time it would entail, has served as a potent tool in motivating Kennecott to clean up the site voluntarily. CERCLA's enforcement and liability provisions, together with Kennecott's real estate opportunities, have resulted in the cleanup of extensive, serious contamination of roughly 93,000 acres.

Estimating benefits from NRDAs

This section contains a description of how the information contained in NRDAs can be used to estimate the benefits of natural resource restoration. It provides a theoretical discussion and a brief example.

The goal of Superfund responses is to remove hazardous substances from natural resources, to prevent them from entering the environment in the first place, or to isolate the substances and prevent further migration. The ecological benefit of the response and/or restoration is the resulting increase in the service flows derived from the improved natural resource. As defined in the courts and in practice, NRDAs cover damages prior to and during response actions, as well as residual damages, if any, following the response and/or removal. The increase in service flows following the removal and/or restoration is not included in this calculation. In effect, NRD claims compensate the public for damages not mitigated by response actions, and the NRD provisions in CERCLA are consistent with a substantial body of law and economics literature that argues that, in order to provide adequate incentives for firms to take precautions to prevent harm to the environment, the responsible parties should bear the full social cost of accidents. More importantly, NRDAs use accepted economic valuation approaches to estimate standard economic measures of WTP, so the information contained in NRDA reports may be useful.

Figure 5.3 illustrates these ideas and suggests several possible outcomes following releases.[10] The horizontal axis represents time, and the vertical axis represents the value of services provided by an ecosystem. Originally, a resource provides a service flow that is valued by various people. This value fluctuates somewhat based on both physical and social factors (e.g., rainfall, or the popularity of sport fishing). At some point hazardous substances are released to the environment, injuring the resource in some way. The figure shows this as a rapid event, but this need not be the case – the damage could occur over a long period of time, as suggested by the “chronic” designation by NOAA for some NRDs.

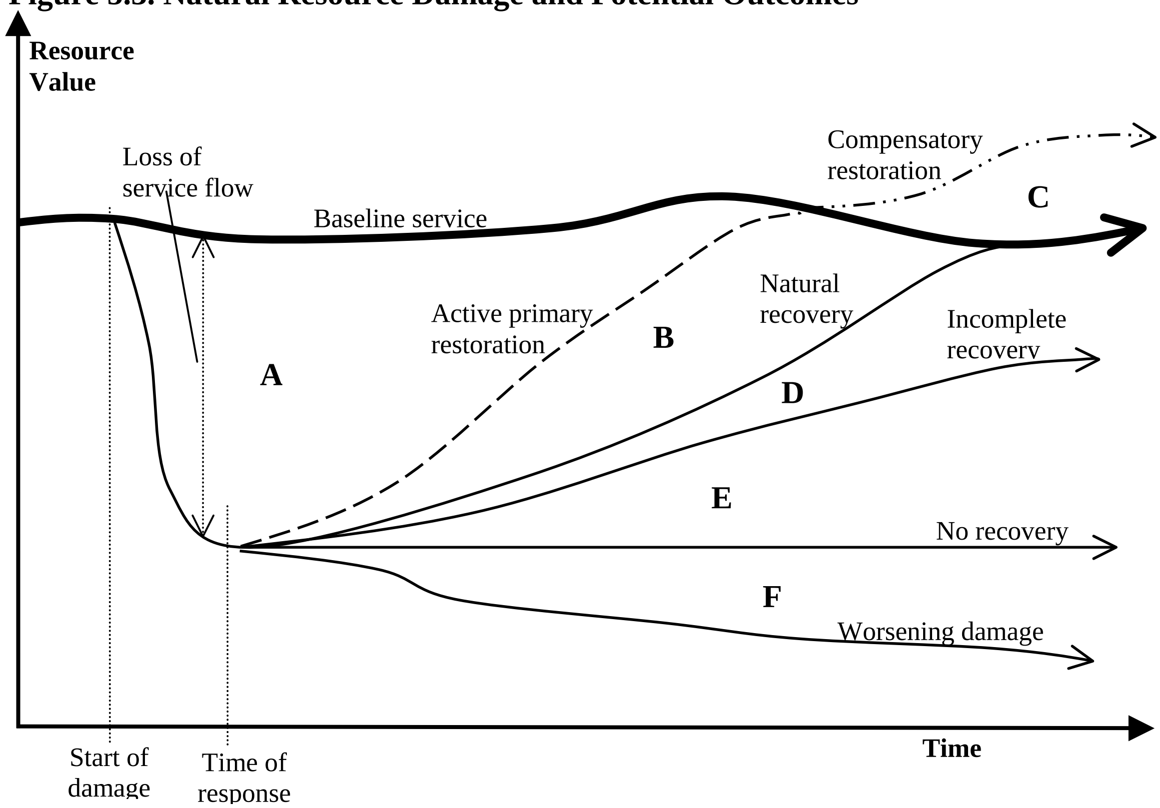
For instance, consider a spill of a hazardous chemical that flows into a tidal wetland area. The spill kills some of the wetland vegetation, and in addition birds, fish, and other animals are exposed to the hazardous substance. The loss of vegetation will reduce the amount of food and shelter (both ecological services) available and the exposure may impair the health or reproduction of wildlife. Other on-site ecological services provided by the wetland that may be impaired by the spill include sediment stabilization, nutrient cycling, and primary productivity. Potentially affected off-site human services, supported by the on-site ecological functions, may include water quality improvements, storm protection, and flood control for shoreline properties, as well as bird watching and commercial and recreational fishing.

If the release stops, for instance if manufacturing operations cease and discharges of pollutants to a water body end; the NRD might take one of several paths shown on Figure 5.3. Damages may remain the same or increase (i.e., the value of the service flow decreases further) until the response occurs. Consider the case of a mining operation that leaves a significant amount of acid-causing mine spoils. These wastes cause damage to the nearby streams and rivers, and

[10] Similar concepts and illustrations are presented in various places in the literature (Kopp and Smith 1989; Carson, Hanemann et al. 1994 p. 248; Jones 2000; Stratus Conusulting 2000, 692.)

continue to do so for year after year. While the mining operations continue, the amount of spoils grows, and the damage continues. At some point, mining stops and, typically, the spoils are left as the firm moves on or goes out of business. The future of the stream might take one of several different paths at this point. The resource might recover naturally. Alternatively, the resource might recover partially, following the "incomplete recovery" path. It might never recover (or not for several generations), so that the resource value would follow the horizontal "no recovery" path. Finally, the resource might continue to degrade, or an engineering solution (e.g., a dam to hold back mine tailings in a river) might fail, reducing ecological service flows further. Then the service flow would follow the "worsening damage" path into the future.

Figure 5.3. Natural Resource Damage and Potential Outcomes



Note: Adapted from (Jones 2000; Breffle et al. 2005).

If a response or a restoration occurs, then the future path changes. For instance, a response action might change the path away from worsening damage to a path that partially restores the service. An example might be a case where abandoned hazardous materials leaking into ground water are destroyed or isolated due to a removal or a remedial action. However, these effects might go largely unrecorded unless there is a programmatic reason to make note of this. In addition, ecological risk assessments are expensive and so such analyses are unlikely to be undertaken. Thus, the ecological benefits of most responses are likely to remain unknown.

The upward change in service flow back towards the baseline could be accelerated by active restoration if a trustee undertakes activities such as restocking a stream that was negatively affected by the contaminated ground water. This could move the future path from, for instance, incomplete recovery to a quicker return to ecosystem health along the “active restoration” pathway. Under some conditions, the ecological service might be enhanced, so the value rises above the historical baseline.

It is possible to define several areas in Figure 5.3 that relate to various losses in service flows. For instance, area *A* is the loss in service flow that occurs prior to any response, plus all subsequent losses, assuming the future of the site is described by the active primary restoration path. Consider the interim period from the time of response to the completion of recovery. The interim lost value associated with the natural recovery scenario (areas *A* + *B*) is higher than for the scenario with active primary restoration actions (area *A*). However, the lost value if no response action occurs, is even larger, either *A*+*B*+*D* if the recovery would be incomplete without response action, or *A*+*B*+*D*+*E* if the resource would not recover without the response action, or *A*+*B*+*D*+*E* +*F* if the response action stopped further damage from occurring. Note that the values for *D*, *E* and *F* as they are shown in Figure 5.3 are not discounted. While it is not difficult to understand how a change in service flows could persist for a very long time (decades to centuries), how to consider values in the distant future is quite complex, as discussed below.

Standard economic theory on benefits identifies the loss of service as a real loss to society, but the compensation paid to the trustee is simply a transfer payment, not a net gain in social welfare. Only the reversal of the physical injury creates a net benefit. The costs of response and restoration are still net costs, and should be minimized.

Estimates of damages and benefits differ in other ways as well. An important distinction is in discounting. The interim damages that NRDAs focus on may last a few years, or several decades, while the benefits created by natural resource restoration may last considerably longer, perhaps centuries. The treatment of benefits in the distant future is not settled in economic theory, and regulations and practice vary significantly on this topic. For instance, Howarth suggests very low (as low as zero) discount rates might be applied in some long-term situations, while Arrow and Manne suggests more standard discount rates of over 5% (Howarth 2003; Arrow 1999; Manne 1995). Some experts have suggested using time-varying discount rates, or choosing the discount rate based on various criteria of the problem at hand (Weitzman 1999; Moore et al. 2004). Practice in conducting NRDAs often leads to losses at a 3% rate, no matter how far into the future, while the EPA *Guidelines* recognize that discounting may sometimes be inappropriate for inter-generational environmental impacts. Thus, they indicate that a “no discounting” scenario should be considered for inter-generational effects (pp. 48-52) and that the way to do this is to display a stream of undiscounted costs and benefits. However, these streams should not be summed. It is not clear what “inter-generational” means in this context; however, the mean and median age of mothers in the United States is about 27 years, so an effect that occurs over more than 30 years could be considered inter-generational (Mathews and Hamilton 2002). Others suggest a 50-year definition (Moore et al. 2004).

Trustee claims about NRDs focus on losses in the past and during the interim before the resource is fully restored, which is area *A* in the figure. In addition, consent decrees include the costs of restoration and the costs of assessment activities. However, some ecological service increases represented by areas B, D, E, and F will also occur. These are the desired outcomes of the response and/or restoration, not the residual damage, and may constitute the majority of the ecological benefits of the Superfund program for that particular site. Although these benefits are not at issue in NRD lawsuits and are not always studied in NRDAs, it is possible to use the data in NRDAs to estimate benefits.

Figures 5.4 and 5.5 are stylized versions of the previous figure that show how ecological benefits will be estimated in this study for two types of sites. Figure 5.4 assumes that the resource recovers naturally over some time period, and that the response and restoration occur instantaneously. In this case, the area of triangle A' represents the past interim losses due to diminution of ecological service flows. The area of triangle A" represents the prospective interim losses imposed on the public while the restoration occurs. In some cases both areas represented by A' and A" are considered interim losses. In other cases, past losses are ignored Neither of these is a benefit. Rather, the area of triangle B represents the benefit of the combined response/restoration. NRDAs typically calculate past and prospective interim losses, represented by the magnitudes of triangles A' and A", although past losses are not always calculated (e.g., Carson et al. 1994; Stratus Consulting 2000). They also typically calculate the costs of the restoration itself, as well as the cost of the assessment.

To use a simple example, assume that it takes ten years from the time of response to the time to restoration, and that natural recovery takes 100 years from the time of response. It is not clear if this should be treated as an intergenerational effect or not. The effect is not permanent, but much of it occurs over a time period grater than thirty years. Thus, using NDRA-derived data about interim damages to understand benefits depends significantly upon assumptions about discount rates. Some parts of the benefits of natural recovery, in this case, would meet the definition of inter-generational given above, suggesting that conventional approaches to discounting might be inappropriate.

Figure 5.5 is a similar stylized representation of the case where there is no recovery without restoration. Some large NRD sites seem to be like this, including Eagle Mine, Idarado, Blackbird Mine, the Clark Fork River, and the Calumet River (Kopp and Smith 1989; State of Idaho vs. M. A. Hanna Company 1995; Stratus Consulting 2000; Industrial Economics Inc. 2004). As in the previous image, the benefit of the response/remedial action is much larger than the interim losses.

Figure 5.4. Natural Resource Benefits with Natural Recovery

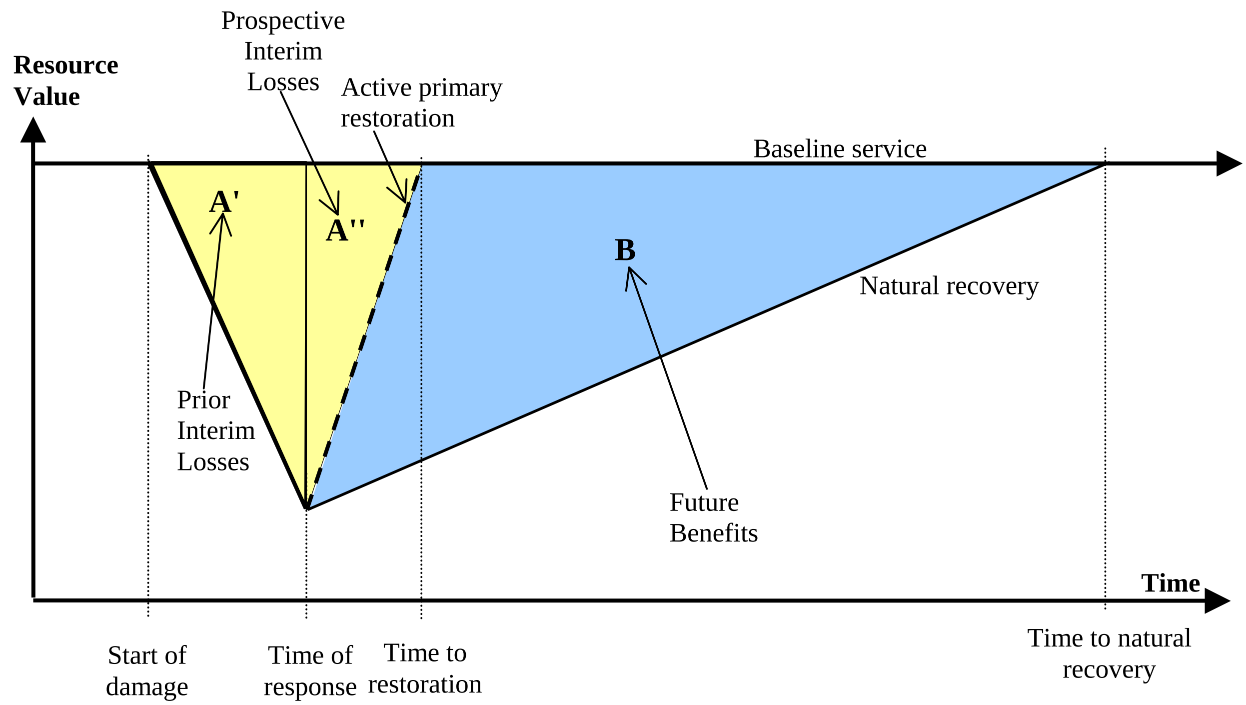
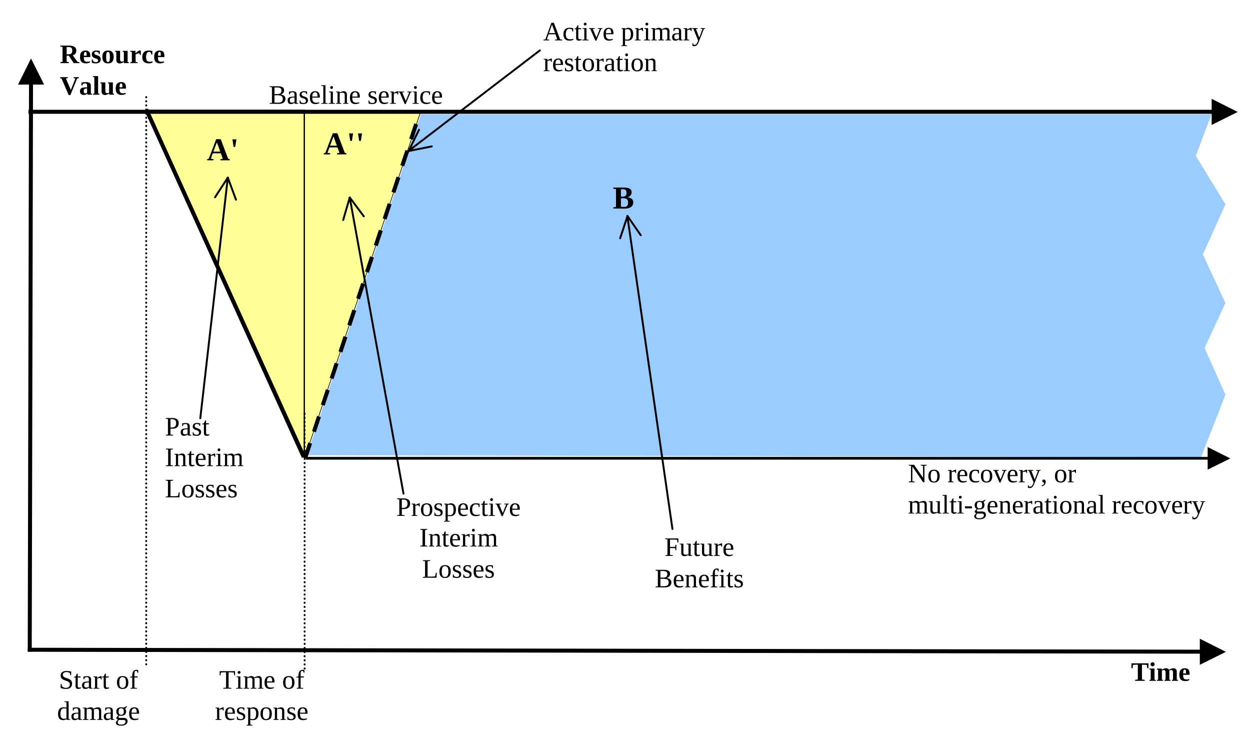
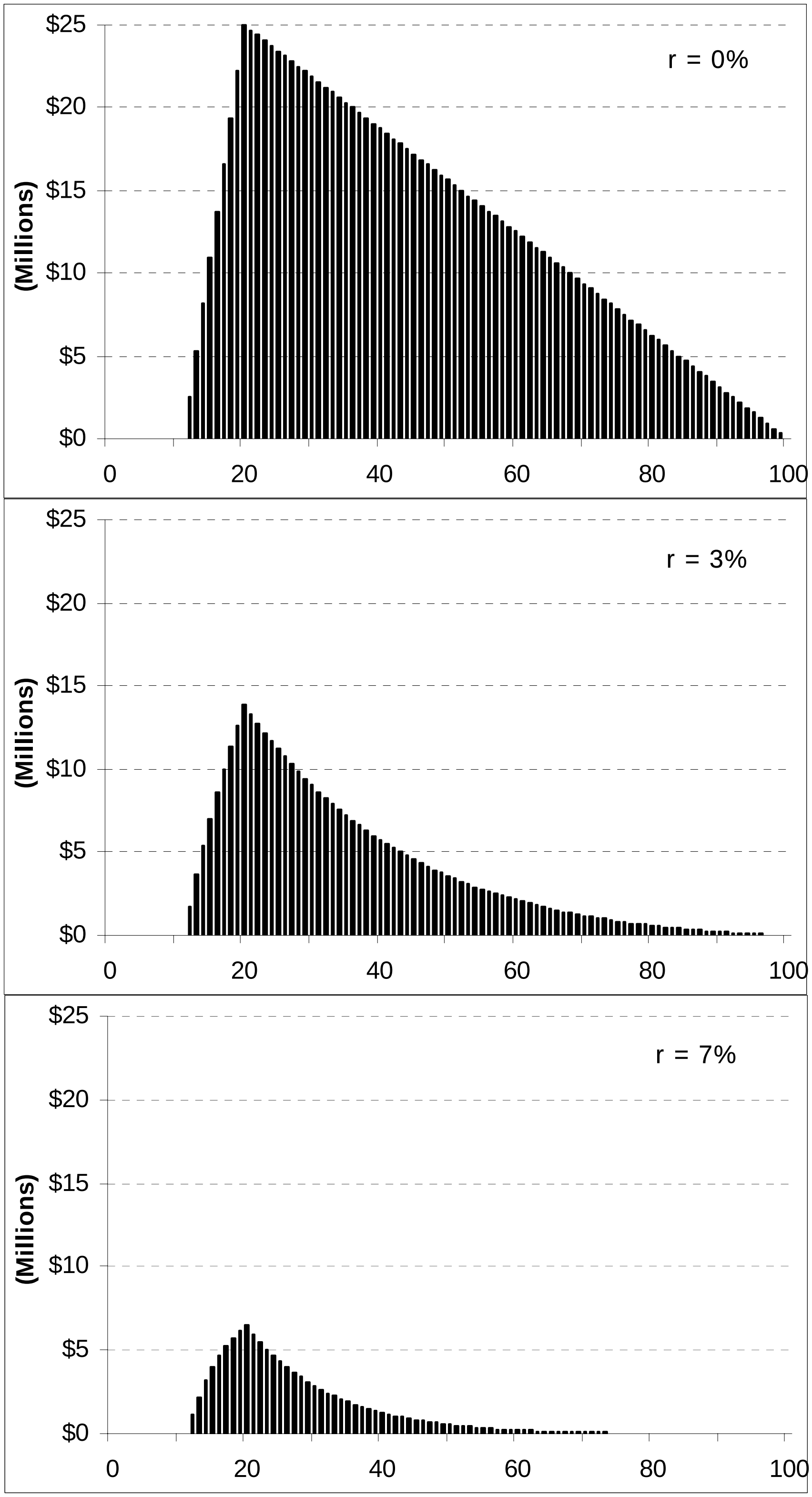


Figure 5.5. Natural Resource Benefits with No Recovery



Data from the Lower Fox River NRDA and settlement can be used to illustrate the approximate magnitude of benefits that the procedure described above produces, and the impact of different choices of discount rates. For the Lower Fox River, the settlement amount is estimated at $42 million, and the present value of the partial WTP for the resulting change is $356 million (The United States of America and The State of Wisconsin v. Fort James Operating Company Consent Decree 2002; Stratus Consulting 2000). The present value of the benefits was created using a 3% discount rate, which was removed to create real, undiscounted annual values for this analysis. This change accelerated the restoration of the ecosystem to twenty years, from a hundred. Figure 5.6 shows how these benefits compare with one another, assuming that benefits do not begin to occur until two years after the completion of a ten-year natural resource restoration, and that natural recovery would have occurred over the course of 100 years. Because benefits are being plotted, not reductions in service flows, the values are positive. The peak benefits occur in about year 20, but the actual value depends strongly on the discount rate that is applied. Annual benefits are shown for discount rates of 0%, 3%, and 7%.

Figure 5.6: Benefits of Restoration of the Lower Fox River, Using Three Different Discount Rates. (2000 $).



Sources: see text.

Further examples of this sort of analysis would better illuminate the potential size of the ecological benefits of the Superfund program. Because a small number of NRD cases make up a large fraction of the settlement total, it may be the case that these natural resource restorations create a significant fraction of the total benefits as well. If the NRDAs for several of the larger cases are located, then a significant fraction of the ecological benefits of natural resource restorations under CERCLA might be estimated. However, smaller settlement amounts may be based on a variety of issues not related to the damages at the site or the potential benefits of restoring the natural resource. Investigation of some smaller NRD cases would be needed to understand this issue better.

If sufficient examples were gathered, it might be possible to extend this analysis and possibly apply the more-widely available data to obtain a more complete estimate of this benefit. One approach might be to take the following steps. First, the size of existing NRD settlements in dollars would be determined. Second, for cases where NRDA data are available, determine the relationship between NRDA estimate of the damages and the NRD settlement. Third, for these cases, use the method described above to estimate the relationship between NRD estimate of damages and the benefits of restoration. These values could be compared across different NRD cases to determine if an estimate for typical values for these ratios can be determined. These estimates might only apply to certain types of NRD cases, for instance river ecosystems. If typical values can be determined, they might be applied in a benefits transfer approach to other NRD cases. However, the number of cases in which NRDA data is available may be insufficient to allow this approach to yield useful results.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach..

Ground Water

Overview

A key goal of Superfund, and in particular of remedial actions at NPL sites, is the protection of ground water. Previous studies of Superfund stress the importance of "environmental and welfare risks that sites pose in addition to current and future health risks … [including] the nonuse value of ground water, which includes the psychological comfort of knowing that ground water is clean" (Walker, Sadowitz, and Graham 1995, 49-50). These authors conclude that, "one of the hidden yet worthy objectives of the program is to protect the quality of our nation's ground water for future yet unspecified uses by humans and nonhuman species". Therefore, the benefits of protecting (or restoring) ground water include not only the willingness to pay for current changes in quantity or quality, but also option, bequest, and existence values. In this study, the amount of ground water protected by Superfund is quantified and a benefits transfer approach is used to monetize the value of protecting ground water. Service flows associated with ground water include domestic uses (i.e., drinking water), water for livestock, commercial use, industrial use, and crop irrigation. Ground water provides these service flows not only to current generations, but to future generations as well.

The purpose of this section is to describe the literature and data associated with the benefits of mitigating ground water contamination and protecting ground water from further contamination. Several approaches that might be used to quantify, and possibly even monetize, the ground water-related benefits of Superfund are described.

Literature on ground water benefits

The existing literature contains many studies that discuss the theoretical aspects of estimating the option, existence, or bequest values of ground water. Most prevalent are CVM studies that examine option values. Table 5.6 summarizes some of the key results in the ground water literature, much of which appears in a recent volume. The two studies in that book that use benefits transfer mainly explore the problems associated with transferring benefits from one ground water study to another and present a fairly skeptical view (Delavan and Epp 2001; VandenBerg et al. 2001). However, the summary chapter is somewhat more positive, arguing that although both benefits transfer studies indicate that the approach does not work well when undertaken between states, "credible transfers could be conducted within each state" (Bergstrom et al. 2001). These authors also believe that there is hope for using benefits transfer techniques in the future but that more research is needed before widespread use is undertaken.

In order to determine the amount of benefits the Superfund program provides related to ground water, the amount of ground water that is contaminated and will ultimately will be remediated or restored through Superfund must be estimated. In addition, it would be useful to know the amount of ground water that will not be contaminated because of Superfund, but would have been contaminated had no Superfund program ever come into being. Quantifying the amount of ground water contaminated on NPL sites is difficult. An estimate of site size in terms of the number of acres can be made, and the sites with contaminated media of ground water can be extracted from CERCLIS. However, this does not provide data on the quantity of ground water that is contaminated, due to the three-dimensional variability of ground water contamination and due to variations in aquifer thickness, porosity, and flow rates.

Monetizing the option, bequest, or existence value of clean ground water is even more difficult. Although there is literature on bequest values, it often does not provide monetized values that would be available for use in a benefit transfer. When values are determined, they are very case-specific and heterogeneous.

Table 5.6. Studies of the Value of Ground Water

Study	Water type	Location	Notes
(Bergstrom , Boyle, and Yabe 2001)	Ground water - nitrate contamination	Georgia and Maine	Do not appear to come up with one range of WTP numbers, but instead estimate several different option price equations and come up with a variety of results for the option price for a ground water protection program in the study counties.
(Delavan and Epp 2001)	Ground water - nitrate contamination	Pennsylvania, Georgia, and Maine	In their benefits transfer study they find that the "difference in mean and median WTP was significant and highly variable with dichotomous choice models but closed rapidly with the addition of a follow-up open-ended question. In short, estimates are easily manipulated and sensitive to methodological changes. Similarly, using the benefits value at one site as the predicted benefits of another would give poor results for benefits transfer in most instances studied."
(Douglas and Taylor 1999)	River stream flows - quantity, not quality	Trinity River, north-central, California	Mean preservation benefits are $106 million for lowest flow and $803 million per year for returning maximum water to the river.
(Dunford 2000)	Ground water - household use only	N/A	"Any potential nonuse values for ground water should be very small from a conceptual perspective, because ground water is ubiquitous. Thus ground-water contamination should not produce significant nonuse damages…..it is very unlikely a reliable estimate of nonuse damages could be developed for ground-water contamination."
(Epp and Delavan 2001)	Ground water - nitrate contamination	Lebanon and Lancaster counties, Pennsylvania	"Estimates of mean and median WTP for the study region are between zero and $67 depending on how the question is asked and whether or not protest bids are included." "…the authors believe that …the mean WTP estimate of $51 should be used."
(Greenley, Walsh, and Young 1981)	River water quality - recreation	South Platte River Basin, Colorado	"WTP additional sales taxes for the option to choose to engage in water-based recreation activities in the future was estimated as $23 annually per household". "About 20 percent of the households interviewed who do not use the River Basin for recreation activities reported they were willing to pay an average of $25 annually for knowledge of the existence of the natural aquatic ecosystem and $17 annually to bequeath clean water to future generations, for a total non-user value of $42 annually". "Average existence value of recreation users was $34 and bequest value $33, for a total non-use value of $67 annually, or 60 percent more."

Table 5.6 (Continued)

Study	Water type	Location	Notes
(Poe 1998)	Ground water - drinking water – nitrate contamination	Portage County, Wisconsin	Their result suggests that estimation of a WTP function for ground water quality is dominated by income and the level of exposure. They say that if their results are supported by future research, transfers of these damage functions to other sites might be accomplished by relatively simple models of income and exposure. They find WTP from $0 for 0 probability of exceeding standards to $516 when probability is 1.
(Poe and Bishop 2001)	Ground water	Portage County, Wisconsin	They "…demonstrate that information effects do occur in risk and exposure perceptions and WTP, and provide the first CVM survey of ground water nitrate contamination to be based on actual exposure levels experienced by respondents." They conclude that "...damage functions based on objective data that is widely available may enhance the possibility of transferring these value to other sites." Their WTP estimates range from $151 for a 0 probability of exceeding standards in the subjective probability model to $569 in the nitrate exposure model when probability is one.
(Poe, Boyle, and Bergstrom 2001)	Ground water	Meta-analysis	They take meta analysis approach where each study is given equal weight. They report three equations, and determine that although there are wide variations in reported WTP values with divergent approaches, the meta analysis indicates that there is a strong systematic element of these studies. They determine that "...the emerging literature on ground water valuation appears to be demonstrating systematic variation."
(Randall, DeZoysa, and Yu 2001)	Enhancements to ground water, surface water, and wetland habitat	Maumee River Basin in northwestern Ohio	They report the estimated mean and lower bound mean WTP ($/household, one time pay) for each of the three programs they offered in their study. All program responses pooled had a median WTP of $32.96 to $52.45, depending on the sample group. Ground water program benefits were $17.55/acre of cropland, while surface water benefits were $26.06/acre cropland, and $21,566 per acre of wetland protected.
(Raucher 1986)	Ground water contamination from waste disposal facilities	Three case studies: 58th Street Landfill in Miami, Davie Landfill near Fort Lauderdale, and Gilson Road Landfill near Nashua, New Hampshire.	They present tables illustrating the benefits and costs for each of the sites with their main conclusions being: 1. potential contamination sites are unique even when similar types exist on the same aquifer 2. benefits do not exceed costs in all cases - responding to an incident may cost less than reducing the probability of contamination 3. corrective actions are not always supported even if drinking water supplies threatened. They use the most economical remedial response costs as an estimate of the benefits of prevention.

Table 5.6 (Continued)

Study	Water type	Location	Notes
(Sun, Bergstrom, and Dorfman 1992)	Ground water - agricultural chemical contamination	Southwestern Georgia	They calculate the mean option price of ground water pollution abatement as $641 annually per household.
(VandenBerg, Poe, and Powell 2001)	Ground water	Twelve towns in Massachusetts, Pennsylvania, and New York	They conduct a benefits transfer using a multi-site CVM study of ground water quality and find evidence to support conclusions that neither the direct nor benefits function transfer approaches are reliable for estimating values at a policy site. However, they think that reliability and accuracy can be improved by grouping sites in meaningful ways. In addition, they find that "...except for the case of the individual site to site transfers, benefit function transfers tend to dominate direct transfers in terms of accuracy."

Therefore, it is not clear if a benefits transfer analysis is appropriate for estimating the value of Superfund in protecting or restoring ground water. However, with ten states of significant diversity included in Table 5.6 (CA, CO, GA, MA, ME, NH, NY, OH, PA, WI), it might be possible to categorize the remaining states into ten relevant categories in order to conduct a benefits transfer analysis.[11] It should be possible to at least quantify the magnitude of the ground water resource that is protected or improved by the Superfund program. The next section addresses this problem.

Ground Water Data

The U.S. Geological Survey reports on water use in the United States (Hutson, Barber, and Kenny 2004). These data show that while the largest use of ground water withdrawals is for irrigation, 23% of ground water withdrawals are used for public and domestic supply. From the perspective of drinking water, 37% of public water supplies are from ground water, as are virtually all private supplies; almost half (46%) of all drinking water in the United States is ground water and thus a large portion of the U.S. population is potentially affected by ground water contamination and remedial action. See Table 5.7.

[11] The EPA Science Advisory Board's advice on this approach, or other, similar approaches, would be greatly appreciated.

Table 5.7. Water Withdrawals in 2000 (million gallons per day)

Water Use Category	Ground water withdrawals	Total water withdrawn from all sources	Ground water withdrawals as percentage of total
Public Supply[12]	16,000	43,300	37%
Domestic[13]	3,530	3,590	98%
Irrigation	56,900	137,000	42%
Livestock	1,010	1,760	57%
Aquaculture	1,060	3,700	29%
Industrial	3,577	19,780	18%
Mining	2,027	3,500	58%
Electric Power	409	195,500	0%
Total	**84,500**	**408,00**	**21%**

Source: (Hutson, Barber, and Kenny 2004)

In order to begin to quantify the amount of ground water potentially protected by Superfund, CERCLIS was queried for sites (NPL and non-NPL) that list one of the contaminated media as ground water. These data were then combined with information from a database that contained information on the size of sites that was created based on RODs, site fact sheets, site list narratives, and CERCLIS. The definition of "site" in CERCLA and the relevant regulations is the extent of contamination, so these site areas give a reasonable measure of the aerial extent of contaminated ground water. The result is list of 1,270 NPL sites with ground water contamination and another 887 non-NPL sites (e.g., sites where response actions have taken place) with ground water contamination. The area of the NPL sites total 4.6 million acres (area data for non-NPL sites are not available). At 162 of the NPL sites with ground water as a contaminated medium, alternative drinking water is one of the response technology types in the CERCLIS database. Many of these areas of contamination have been controlled or reversed through Superfund response actions, and there may be some sites where removal actions or state actions may have prevented potential ground water contamination. Thus, there appears to be a significant ground water resource protected by Superfund, although the actual extent is not clear.

Methodology

This study proposes further investigating these related data in order to better quantify the amount of ground water protected or restored by the Superfund program. It is clear that based on the previous literature, people care about ground water for both current and future generations. This study can probably answer the question, "What fraction of all aquifers in the nation does Superfund protect?" This question could be answered by using the U.S. Geological Survey's

[12] "Public supply refers to water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections. Public water may be delivered to users for domestic, commercial, industrial, or thermoelectric-power purposes." (Hutson, Barber, and Kenny 2004, 13)

[13] Here, "…domestic use refers to self-supplied withdrawals only. For self-supplied domestic water, the source usually is a well." (Hutson, Barber, and Kenny 2004, 16)

GIS map layer that gives the principal aquifers in the U.S. If these data are combined with the latitude and longitude and acreage data for the CERCLIS sites with ground water as a contaminated media, then an estimated fraction of the U.S. aquifers that are affected by Superfund could be obtained. It might be possible to go further and estimate the amount of ground water that will not be contaminated because of Superfund, but would have been in the baseline case where no Superfund program had ever come into being.

This study further proposes doing a meta-analysis of individual studies to get a range of willingness to pay for ground water quality, and possibly placing states into groups based on relevant metrics. This WTP range and category-based estimate could then be compared with some uniform metric such as household income. This may allow the development of a WTP for ground water as a percentage of income. The feasibility of this approach would depend on the ability for both the effect of Superfund on ground water quality and the WTP for ground water quality to be estimated in compatible units.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

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